

BIOSENSOR ELECTROMAGNETIC NOISE CANCELLATION

Background of the Invention

In the past, it has been found desirable to use amperometric analysis of biosensing cell assemblies. Such analysis was possibly subject to electromagnetic interference because of the loop formed by such cells in their disposable form, wherein a pair of conductors were supported on an insulating substrate with a remote test cell completing the circuit for analysis of a response current, which in one embodiment may be a Cottrell current. In the prior art, any stray electromagnetic fields present to the biosensing cell assembly may cause a spurious signal ("noise"), interfering with and distorting the response current. The present invention overcomes this difficulty by providing a noise cancellation apparatus and method to improve the measurement of the response current in such biosensing cell assemblies.

Brief Description of the Drawings

Figure 1 is a prior art biosensing cell assembly.

Figure 2 is a biosensing cell assembly according to the present invention.

Figure 3 is a circuit diagram of a simplified circuit useful for energizing and measuring the response current in the biosensing cell assembly of Figure 2.

Figure 4 is a simplified block diagram of the biosensing cell assembly of Figure 2 and the circuit of Figure 3.

Figure 5 is a second embodiment of a biosensing cell assembly according to the present invention.

Figure 6 is a section view along line 6-6 of Figure 5.

Figure 7 is a still further embodiment of a biosensing cell assembly shown inserted into an instrument housing for energizing and reading the cell assembly according to the present invention.

Figure 8 is a view similar to that of Figure 7, but with the biosensing cell assembly removed from the instrument housing and showing further aspects of this embodiment of the present invention.

Figure 9 is a simplified electrical schematic of another form of a circuit useful for energizing and measuring the response current in the biosensing cell assembly according to the present invention.

Detailed Description of the Invention

Referring now to the figures, and most particularly to Figure 1, a prior art biosensor cell assembly 10 includes a pair of electrodes or conductors 12 and 14 which are supported on a polymeric sheet or substrate 16. A cover sheet 18 is provided with openings 20 and 24 which expose the conductors 12 and 14. Opening 20 creates a well and provides access to a reaction zone 22 between conductors 12 and 14. A gel-like layer (not shown) or other form of reactants overlays conductors 12 and 14 to form reaction zone 22. In operation, an analyte-containing fluid sample is preferably placed on the reaction zone 22 to determine the concentration of analyte using amperometric analysis. The prior art assembly 10 may be subject to electromagnetic interference when undergoing amperometric analysis, more particularly, stray electromagnetic fields may pass through a measurement loop 26 formed by the conductors 12 and 14 and the reaction zone 22. It is to be understood that the measurement loop 26 will form a complete circuit when connected to an instrument (as will be described *infra*) to perform the amperometric analysis.

Referring now to Figure 2, a first embodiment of the biosensor cell assembly 30 of the present invention may be seen. In this embodiment, the measurement loop 26 is the same or similar to that shown in Figure 1. In addition, however, there is a noise cancellation loop 32 physically arranged to be exposed to substantially the same electromagnetic environment as the measurement loop 26. The

noise cancellation loop 32 includes a pair of spaced apart conductors 34, 36 and a predetermined impedance 38. Impedance 38 may be a resistor and is preferably within a range of the impedance of the reaction zone or test cell 22 when the test cell 22 is amperometrically monitoring a response current to provide an indication of the analyte concentration being measured. For example, if the test cell 22 varies between 20K ohms and 100K ohms for various analyte concentrations to be measured, impedance 38 is preferably selected to be between 20K ohms and 100K ohms, and most preferably about 60K ohms, for a range of amperometric response currents from 10 to 50 microamperes.

As may be seen in Figure 2, loop 32 closely surrounds loop 26, generally circumscribes the same area, and is in generally the same plane, so that any ambient electromagnetic field will affect or influence loops 26 and 32 substantially the same. More particularly, any error current induced in measurement loop 26 will be substantially the same as an error current induced in the noise cancellation loop 32. Since loop 32 has a known, fixed impedance, the error current may be removed from loop 26 by subtracting the error current in loop 32. It is to be understood that the error currents and error subtraction occur only when the assembly 30 is connected to an instrument for amperometric analysis.

The electrical circuit schematic 40 for such a connection is shown in Figure 3. In this circuit 40, test cell 22 is connected to an amplifier 42 and powered by a DC voltage source 44. Measurement loop 26 will thus have a response current flowing through conductors 12 and 14 in a counterclockwise direction 46. The noise cancellation loop 32, formed by conductors 34 and 36 and resistor 38 will have a current produced by source 44 flowing therethrough in a clockwise direction 48. Loop 32 may thus be seen to be arranged to be in an "anti-parallel" relationship with loop 26. Since a stray ambient electromagnetic field will induce substantially the same currents in each of loops 32 and 26 (i.e., the induced currents will be substantially the same in magnitude and in direction), the total currents in those loops may be added together at the negative summing junction 51 of amplifier 42, canceling or reducing the effect of the electromagnetic interference. It is to be understood that

the DC current through resistor 38 will be a fixed offset to the response current in loop 26 and can be accounted for in a conventional manner. Resistor 38 preferably has a “flat” frequency response, such that the impedance in the noise cancellation loop 32 is substantially frequency independent. It is to be understood, however, that there is an inductance associated with each of the loops 26 and 32, and that such inductances are preferably made as similar as possible, such that the total impedance of loop 32 has substantially the same frequency response as the total impedance of loop 26, taking into account the conductors, any stray capacitance, and the test cell 22 (for loop 26) or resistor 38 (for loop 32). The voltage source 44 and amplifier 42 provide the means for determining the response current to provide an indication of an analyte concentration in the test cell or reaction zone 22.

It is to be further understood that the amperometric response current measured by the circuit 40 of Figure 3 will have a modified characteristic from that when the prior art sensor 10 is used without the noise cancellation loop. More particularly, when the noise cancellation loop 32 is connected, the change in impedance of test cell 22 will be that of a variable resistor (depending upon analyte concentration) in parallel with a fixed resistor 38. The gain of circuit 40 will be the ratio of a feedback resistor 50 to the parallel equivalent of the impedances 22 and 38. Conventional offset and calibration subcircuits (not shown) may be used with amplifier 42 according to well-known techniques. It is to be understood that the output 52 of operational amplifier 42 is preferably further processed to provide signal conditioning by additional circuitry (also not shown). Such additional circuitry may include scaling, switching, and analog to digital conversion, as is well known for amperometric analysis of response currents, for example measurement and display of glucose concentration in the reaction zone 22 by measurement of Cottrell current.

Referring now to Figure 4, an alternative embodiment of the biosensing cell assembly 130 may be seen. In this embodiment, the measurement loop 26 and the noise cancellation loop 32 are positioned adjacent each other on a common substrate 116. Even though the same field lines will not pass through both loops, such an arrangement will expose both loops to substantially the same electromagnetic

environment, especially where field gradients are low, as is expected in the regions where amperometric analyses are expected to take place.

Referring now to Figures 5 and 6, a still further alternative embodiment of a biosensing cell assembly 230 may be seen. In this embodiment, the measurement loop 26 is located on one side of a substrate 216, while the noise measurement loop 32 is located on other side of substrate 216. In this embodiment, loops 26 and 32 are preferably substantially congruent to each other and separated only by the thickness of substrate 216.

Referring now to Figures 7 and 8, a still further alternative embodiment of the present invention may be seen. This embodiment makes use of the prior art biosensing cell assembly 10 and provides a shelf or support 54 carrying the noise cancellation loop 32. In operation, assembly 10 carrying conductors 12 and 14 and reaction zone 22 of the measurement loop 26 is inserted into a measuring instrument 56, as shown in Figure 7. As may be most clearly seen in comparison with Figure 8 (showing the noise cancellation loop 32 in shelf 54) the measurement loop 26 will be physically aligned with (and generally preferably substantially congruent to) the noise cancellation loop 32 when the test strip or assembly 10 is inserted into the instrument 56. Thus this embodiment has the instrument 56 electrically connectable to the measuring loop 26 and has the noise cancellation loop 32 located on the structure 54 adjacent the measurement loop 26 when the measurement loop is connected to the instrument.

Referring now to Figure 9, an alternative (simplified) schematic 340 for the biosensing cell assembly 330, power source 344 and amplifier 342 may be seen. In this embodiment it is to be understood that the response current caused by voltage source 344 flows in a counterclockwise direction 46 in the measurement loop 26. Similarly, current caused by voltage source 344 in the noise cancellation loop 32 flows in a counterclockwise direction, indicated by arrow 46. The noise cancellation loop 32 is connected to an inverting input 62 of an amplifier 64. An output 66 of amplifier 64 is connected through a summing resistor 70 to the inverting input 51 of amplifier 342. A feedback resistor 68 is connected between the inverting input 62

